

Supplementary material
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Magnetocarcinogenesis: is there a mechanism for carcinogenic effects of weak magnetic fields?

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Table S1. Studies on the effects of magnetic fields (MF) on circadian rhythms in animals and cell cultures.

Assay	MF exposure	Co-exposure	Response to MF	Reference
Diurnal rhythm of the pain threshold in mice	60 Hz, 1.5 mT, 12 h/d for 5 d	Constant darkness	The diurnal rhythm was attenuated or restored depending on the time of MF exposure; MF acted like light	Choi et al., 2003
Melatonin cycles in cows	60 Hz, 30 µT, 16 h/d for 4 wk	50 Hz electric field, 10 kV/m	Increased day-night difference in melatonin levels	Rodriquez et al., 2004
Melatonin production in mice	50 Hz, 0.1 mT, 52 d	None	Increased day-night difference in melatonin production	Kumlin et al., 2005
Locomotor activity in <i>Drosophila</i> flies	Static, 0.15-0.5 µT	Blue or red light	Lengthening of the circadian period. Response only in the presence of blue light. <i>Cry</i> mutant status affected the response.	Yoshii et al., 2009
Locomotor responses in <i>Drosophila</i> flies	Static or 3-50 Hz, 0.09-1 mT	Blue or green light	Increased activity, shortening or lengthening of the circadian period depending on light wavelength. Increased rhythmicity among flies overexpressing CRY (which tended to be arrhythmic)	Fedele et al., 2014
Expression of circadian clock genes in human dermal fibroblasts	50 Hz, 0.1 mT	Starvation, serum shock stimulation	Induction of circadian variation in the expression of <i>BMAL1</i> , <i>PER2</i> , <i>PER3</i> , <i>CRY1</i> , and <i>CRY2</i> by a 1-h MF exposure. Continuous MF increased the amplitude of clock gene oscillations triggered by serum shock	Manzella et al., 2015

Table S2. Studies on the effects of ELF magnetic fields (MF) on DNA damage responses and cell cycle.

Assay	MF exposure	Co-exposure	Response to MF	Reference
Cell cycle kinetics in yeast (<i>Saccharomyces cerevisiae</i>)	50 Hz, 0.12 mT, 430 min	UVB radiation 175 J/m ² in the beginning of MF exposure	Enhanced G ₁ -arrest at 60 min after UV irradiation	Markkanen et al., 2001
Apoptosis, expression of the p53 protein in mouse skin	50 Hz, 0.1 mT, 24 or 48 h	UV radiation 400 J/m ² for 1 h prior to MF exposure or between MF exposures	Suppression of UV-induced apoptosis	Kumlin et al., 2002
Cell cycle distribution, DNA synthesis, expression of cell cycle regulating proteins in human amniotic fluid cells	50 Hz, 1 mT, 0-30 h	None	Decreased DNA synthesis, time-dependent changes in expression cyclin D1, p16 and p21	Lange et al., 2002
Apoptosis, DNA repair, proliferation in human cancer cell lines HL-60, HL-60R and Raji	60 Hz, 0.15 mT, 4, 12 or 24 h	Heat shock for 1 h after MF exposure. 1 mM H ₂ O ₂ in DNA repair assay	≥12 h exposures: suppression of heat-induced apoptosis, decreased DNA repair rate	Robison et al., 2002
Cell cycle distribution, expression of cell cycle regulating proteins in human amniotic fluid cells	50 Hz, 1 mT, 0-30 h	γ radiation 0, 2, 4 or 8 Gy before MF exposure	Time-dependent changes in expression of cyclin D1, p21 and p16. No enhancement of the effects of γ radiation	Lange et al., 2004
Cell cycle distribution in murine L929 cells	50 Hz, 0.1 or 0.3 mT, 24 h	Menadione 150 μM for 1 h or UVB radiation 160 J/m ² using various exposure schedules	MF exposure before menadione: decreased apoptosis and increase of G ₂ /M cells. At 0.3 mT also G ₁ cells were decreased	Markkanen et al., 2008
Proliferation, cell cycle distribution and mRNA levels of p21 in human BE(2)C neuroblastoma cells.	50 Hz, 1 mT, 24-72 h	Simultaneous exposure to all-trans-retinoic acid (ATRA) 5 μM	Increase in G ₀ /G ₁ , decrease in G ₂ /M, S and sub-G ₀ /G ₁ cells. Increased expression of p21. Effects only in presence of ATRA	Marcantonio et al., 2010
DNA strand breaks, DNA repair and micronuclei in human SH-SY5Y neuroblastoma cells	50 Hz, 0.1 mT, 24 h	Menadione 0.1-20 μM or methyl methanesulphonate 10-35 μg/ml for 3 h after MF exposure	Increased DNA damage, DNA repair rate, and micronucleus formation	Luukkonen et al., 2011
Gene expression, expression of the ATM-Chk2-p21 pathway proteins and cell cycle distribution in human HaCaT keratinocytes	60 Hz, 1.5 mT, 144 h	None	Altered mRNA expression of cell cycle-related genes, increased levels of phospho-ATM, phospho-Chk2 and p21. Increase in G ₀ /G ₁ and decrease in S cells	Huang et al., 2014
DNA double-strand break repair in embryonic mouse brain	In utero 50 Hz, 0.3 mT, 3 h before and up to 9 h after X-rays	X-rays, 100 mGy, between MF exposures	No effects	Woodbine et al., 2015
DNA strand breaks, expression of proteins involved in DNA damage responses, cell cycle distribution in human SH-SY5Y neuroblastoma cells	50 Hz, 0.1 mT, 24 h	Menadione 1-25 μM for 1 or 3 h after MF exposure	Increase in G ₁ and decrease in S cells. Decreased p21 protein level. MF effects were independent of menadione treatment	Luukkonen et al., 2017

Table S3. Studies on the effects of ELF magnetic fields (MF) on cellular superoxide (O_2^-) levels.

Assay	MF exposure	Co-exposure	Response to MF	Reference
Level of cytosolic O_2^- in human K562 leukaemia cells	50 Hz, 0.025-0.1 mT, 1 h	Phorbol 12-myristate 13-acetate (PMA), 1,10-phenanthroline, melatonin	Increased O_2^- level. No interaction with PMA. Antioxidants phenanthroline and melatonin inhibited the MF effect	Mannerling et al., 2010
Levels of ROS, mitochondrial and cytosolic O_2^- , reduced GSH, and lipid peroxidation in human SH-SY5Y neuroblastoma cells	50 Hz, 0.1 mT, 24 h	Menadione for 3 h after MF exposure	Increased ROS and mitochondrial O_2^- levels, decreased level of reduced GSH. No clear MF*menadione interaction	Luukkonen et al., 2014
Levels of mitochondrial and cytosolic O_2^- in SH-SY5Y and in murine C6 glioma cells	50 Hz, 0.01 or 0.03 mT, 24 h	Menadione for 3 h after MF exposure	Increased mitochondrial and cytosolic O_2^- levels in C6 cells. No MF*menadione interaction	Kesari et al., 2016
Mitochondrial O_2^- level in human FL amniotic cells	50 Hz, 0.4 mT, 30-120 min	None	Increased O_2^- level after 30 and 120 min but not after 60 min of MF exposure	Feng et al., 2016
Levels of mitochondrial and cytosolic O_2^- in SH-SY5Y cells	50 Hz, 0.1 mT, 24 h	Menadione during the last 3 h of MF exposure, blue light during MF exposure	Decreased mitochondrial and increased cytosolic O_2^- levels. No MF*menadione interaction. Blue light decreased mitochondrial O_2^- level and blocked MF effect on cytosolic O_2^- .	Höytö et al., 2017

Table S4. Studies on the effects of ELF magnetic fields (MF) on genomic instability.

Assay	MF exposure	Co-exposure	Response to MF	Reference
Micronuclei and aneuploidy in human CCD-986sk fibroblasts 28, 88 and 240 h after exposure to BLM	60 Hz, 0.8 mT for up to 240 h	Bleomycin (BLM) 0, 0.2, or 1 μ g/ml for 3 h before MF exposure	Enhancement of BLM-induced micronuclei and aneuploidy	Cho et al., 2007
Microsatellite mutations in human UVW glioma cells 38 d after the exposures	50 Hz, 1 mT, 12 h	γ radiation 0, 0.3 or 3 Gy prior to MF exposure	Increased microsatellite mutations with and without γ radiation. The effect was particularly pronounced for allelic imbalance, which indicates genomic instability	Mairs et al., 2007
Micronuclei in human SH-SY5Y neuroblastoma cells 8 and 15 d after the exposures	50 Hz, 0.1 mT, 24 h	Menadione 1 or 20 μ M for 3 h after MF exposure	Increased level of micronuclei with and without menadione	Luukkonen et al., 2014
Micronuclei in human SH-SY5Y neuroblastoma cells 15, 30 and 45 d after the exposures	50 Hz, 0.1 mT, 24 h	N-acetyl cysteine (NAC) for 1 h before, and menadione 20 μ M for 3 h after MF exposure	Increased level of micronuclei at 15 and 30 d with and without menadione. The antioxidant NAC did not block the MF effect	Kesari et al., 2015

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